UNIVERSITY OF WYOMING
Office of Research & Economic Development

Radiation Safety Program
Office: Wyoming Hall Room 102
Phone: (307) 766-2638
Email: herrold@uwyo.edu

Laser Safety Plan

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I. Scope

A. The University of Wyoming (UW) has the fundamental responsibility for the assurance of the safe use of lasers owned and/or operated in facilities under its control. Hence, this plan applies to all such lasers and laser systems.

II. Regulations and standards

A. Occupational Health and Safety Administration (OSHA) 29 CFR 1910.97 (Nonionizing radiation); 29 CFR 1910.132 (General requirements); and 29 CFR 1910.133 (Eye and face protection).

B. Food and Drug Administration (FDA), Center for Devices of Radiological Health regulations in 21 CFR Part 1040.

C. American National Standards Institute, ANSI Z136.1-2014 (Safe Use of Lasers) ANSI Z136.8-2012(Safe Use of Lasers in Research, Development, or Testing), and ANSI Z136.5-2009 (Safe Use of Lasers in Educational Institutions).

III. Classification of lasers

Table 1: Typical Classification of Lasers (see ANSI Z135.1-2014 for more details)

Class	Power Output	Description
1	< 0.4 µW	(Former Class IIa are treated as Class 1) Considered incapable of producing damaging radiation levels during normal operation. (e.g., laser printers.) Exempt from any control measures. **May contain higher class lasers and produce laser hazards if operated with interlocks defeated.** Only authorized personnel may operate Class 1 laser systems with interlocks defeated.
1M	< 0.4 µW	Considered incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope) and is exempt from any control measures other than to prevent potentially hazardous optically aided viewing.
2	0.4 µW to 1 mW	Emits in the visible portion of the spectrum (400 to 700 nm) at a power level of 1 mW or less. (e.g., laser pointers.) The normal aversion response to bright light is adequate protection. Staring into the beam of a Class 2 laser is hazardous.
2M	0.4 µW to 1 mW	Same as Class 2, except that viewing the beam with collecting optics (e.g., telescope) is potentially hazardous.
3R	1 mW to 5 mW	Potentially hazardous under some direct and specular viewing conditions if the eye is focused and stable, but the probability of actual injury is small. Operators of Class 3R laser systems shall receive a laser safety briefing.
3B	5 mW to 500 mW	Eye hazard for direct and specular reflection viewing, even for momentary exposures. Not a hazard for diffuse reflections or for generating fire or laser generated air contaminants. Class 3B laser systems shall be operated only in laser controlled areas by authorized operators.
4	> 500 mW	Eye hazard and skin hazard for intrabeam exposures, specular and diffuse reflections. Also a fire hazard and may produce laser generated air contaminants and hazardous plasma radiation. Class 4 laser systems shall be operated only in laser controlled areas by authorized operators. A written Safety Procedure (SP) is required for Class 4 laser operation.

Table 2. Administrative Requirements by Laser Classification				
Class	**Procedural & Administrative Controls (Table 3)**	**Laser Safety Training**	**Medical Surveillance**	**Registration with LSO**
1	Not Required	Not Required (1)	Not Required	Not Required
1M	**Required**	Briefing (1) (3)	Depends on Application (3)	Depends on Application (3)
2	Depends on Application (2)	Briefing (1) (2)	Not Required	Not Required
2M	Required	Briefing (1) (3)	Depends on Application (3)	Depends on Application (3)
3R	Depends on Application (2)	Briefing (1) (2)	Not Required	Depends on Application (2)
3B	**Required**	**Training Required**	Suggested	**Required**
4	**Required**	**Training Required**	Suggested	**Required**

Note: During maintenance and service the classification associated with the maximum level of accessible laser radiation shall be used to determine the applicable control measures.

1) Operators of Class 1, 1M, 2,2M, and 3R lasers, and Class 1 laser systems with embedded Class 3B or Class 4 lasers, should receive a laser safety briefing.
2) Not required except for conditions of intentional intrabeam exposure applications
3) Certain uses of unsupervised Class 1M or 2M lasers of laser systems that exceed Class 1 of Class 2 may require hazard evaluation and/or labeling.

IV. Organization and responsibilities

A. Laser Safety Officer (LSO)

1. An individual designated by the administration as the Laser Safety Officer (LSO) shall have the responsibility and authority to assure compliance with this plan.

2. Laser Safety Officer responsibilities

a. Assure the proper classification of all lasers

b. Perform hazard evaluations for all Class 3B and 4 lasers and laser work areas

c. Specify control measures for all Class 3B and 4 lasers and assure implementation

d. Approve laser procedures, lesson plans, facilities, protective equipment, signs and labels

e. Assure that all laser personnel receive appropriate safety training

f. Monitor the program, assure compliance and maintain program records

3. The LSO shall have final authority in determining laser control measures and may approve alternate controls when these are appropriate. Class 3B and Class 4 lasers shall be operated only with the written approval on the LSO. The LSO shall have the authority to terminate laser operations at any time.

4. The LSO may appoint a Deputy Laser Safety Officer (DLSO) and may delegate duties to the DLSO in accordance with ANSI Z136.1.

B. Laser Safety Committee (LSC)

1. Membership of Laser Safety Committee

   a. The LSC should include the LSO, administration representatives, and representatives of the departments or divisions using lasers who, by knowledge and experience, are qualified in the area of laser safety.

   b. Members shall be appointed by their respective departments/division heads for periods of up to three years.

2. Laser Safety Committee responsibilities

   a. The LSC reviews laser safety policies, procedures and training and provides consultation to the LSO as administrative and technical content experts.

   b. The LSC reviews issues of concern arising from incidents, accidents, and laser hazard assessments, and makes recommendations for appropriate actions.

C. Laser Supervisor (LS)

1. A University of Wyoming faculty or staff member with primary responsibility for any use, maintenance or service of a Class 3B or Class 4 laser.

2. Laser Supervisor responsibilities

   a. Registration of all Class 3B and Class 4 laser systems with the Laser Safety Officer.

   b. Posting required signs, enforcing access control, providing protective eyewear as required, and informing personnel of potential hazards.

   c. Identify which persons are authorized to operate a laser system under his/her control and ensure that all laser users receive approved laser safety training.

d. Be familiar with the standard operating procedures and ensure that they are provided to users of such lasers.

e. Notify the LSO of known or suspected laser-related incidents and accidents. The supervisor shall cooperate with the LSO and/or LSC during the course of their investigation and implement corrective actions to prevent a recurrence.

D. Authorized laser operators

1. No one shall energize or work with or near Class 3B or 4 a lasers with exposed beams unless authorized to do so by the supervisor for that laser.

2. All authorized laser operators shall be familiar and comply with all applicable safety rules and procedures prescribed by the supervisor and the LSO.

3. When a laser operator knows or suspects that an accident has occurred involving a laser, and that such accident has caused or could have potentially caused an injury, he or she shall immediately inform the supervisor or the LSO.

V. Training requirements

A. All operators of embedded Class 3B or 4 lasers and of Class 1M, 2, 2M, and 3R lasers and laser systems and all incidental personnel or spectators who may be allowed to enter laser controlled areas should receive a laser safety briefing before operating the laser or entering the controlled area.

B. All operators of Class 3B and 4 lasers shall receive approved laser safety training before operating the laser. This training includes:

1. Familiarity with this Laser Safety Plan

2. Documented laser safety training, provided or approved by the LSO

3. Documented laboratory-specific safety training, including applicable standard operating procedures.

VI. Control measures

A. Acquisition and approval of Class 3B and 4 lasers

1. Note: Laser systems that are purchased, acquired through transfer, or built by researchers must meet certification as stipulated in Title 21, Code of Federal Regulations, Part 1040. It is the responsibility

of the acquiring department or Laser Supervisor to ensure these requirements.

2. The Laser Supervisor shall notify the LSO prior to the acquisition or construction of any Class 3B or 4 laser system.

3. The Laser Supervisor shall submit to the LSO for review all new and modified standard operating procedures for Class 3B and Class 4 laser installations.

B. Design standards

1. Whenever possible, Class 3B or 4 lasers shall be equipped with:

   a. A protective housing that encloses the beam path and is interlocked to prevent access (i.e., embedded Class 3B or Class 4).

   b. An aperture that is clearly identified, and

   c. A clearly marked keyed master switch (or computer code) to deactivate the laser or reduce its output to less than maximum permissible exposure (MPE).

2. If these conditions are not all possible, a laser hazard assessment shall be effected by the LSO and appropriate controls shall be put into place, including but not limited to the following.[1]

   a. Access restriction (laser controlled area)

   b. Eye protection

   c. Area controls

   d. Diffusely reflecting barriers, shrouds, beam stops, etc.

   e. Administrative and/or procedural controls

   f. Education and training

3. Viewing ports and collecting optics shall provide adequate protection to maintain exposure at viewing position at or below the MPE level. (Classes 2, 3, or 4). Use only materials that are non-combustible and will not produce laser generated airborne contaminants (LGAC).

[1] See Table 3 for details.

Table 3. Control Measure Requirements for Lasers (ANSI Z136.1-2014 Tables 10 and 11*)[2]							
Engineering Control Measures (*ANSI Table 10a.)	**Classification**						
	1	**1M**	**2**	**2M**	**3R**	**3B**	**4**
Protective Housing (ANSI 4.4.2.1)	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Without Protective Housing (ANSI 4.4.2.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (ANSI 4.4.2.1.3)	▼	▼	▼	▼	▼	**X**	**X**
Service Access Panel (interlock /tool required, ANSI 4.4.2.1.4)	▼	▼	▼	▼	▼	**X**	**X**
Key Control (or computer code, ANSI 4.4.2.2)	–	–	–	–	–	●	●
Viewing Windows, Display Screens and Diffuse Display Screens (ANSI 4.4.2.3)	Assure viewing limited < MPE						
Collecting Optics (e.g., lenses, microscopes) (ANSI 4.4.2.6.)	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Fully Open Beam Path (4.4.2.7.1) and Limited Open Beam Path (4.4.2.7.2) (laser hazard evaluation required)	–	–	–	–	–	**X** NHZ	**X** NHZ
Enclosed Beam Path (ANSI 4.4.2.7.3)	Further controls not required if 4.4.2.1 and 4.4.2.1.3. fulfilled						
Laser Emission Warning, audible/visible (ANSI 4.4.2.9)	–	–	–	–	–	●	**X**
Laser Controlled Area (UWLSP VI.C.6.b) (ANSI 4.4.2.10)	–	–	–	–	–	**X**	**X**
Entryway Controls (ANSI 4.4.2.10.3) (UWLSP VI.C.6.b.vi)	–	–	–	–	–	–	**X**
Protective Barriers and Curtains (ANSI 4.4.2.5)	–	–	–	–	–	●	●
Administrative/Procedural Controls (ANSI Table 10b.)							
Standard Operating Procedures (ANSI 4.4.3.1)	–	–	–	–	–	●	**X**
Output Emission Limitations (ANSI 4.4.3.2)	–	–	–	–	LSO Determination		
Education and Training (UWLSP: V) (ANSI 4.4.3.3.)	–	●	●	●	●	**X**	**X**
Authorized Personnel (ANSI 4.4.3.4)	–	–	–	–	–	**X**	**X**
Indoor Laser Controlled Area (ANSI 4.4.3.5)	–	Φ	–	Φ	–	**X** NHZ	**X** NHZ
Temporary Laser Controlled Area (ANSI 4.4.3.5)	▼ MPE	▼ MPE	▼ MPE	▼ MPE	▼ MPE	–	–
Controlled Operation (ANSI 4.4.3.5.2.1)	–	–	–	–	–	●	●
Outdoor Control Measures (ANSI 4.4.3.6)	**X**	Φ NHZ	**X** NHZ	Φ NHZ	**X** NHZ	**X** NHZ	**X** NHZ
Laser in Navigable Airspace (ANSI 4.4.3.6.2)	●	●	●	●	●	●	●
Alignment Procedures (ANSI 4.4.3.8)	▼	**X**	**X**	**X**	**X**	**X**	**X**
Spectators (ANSI 4.4.3.6)	–	Φ	–	Φ	–	●	**X**
Service Personnel (ANSI 4.4.3.9)	LSO determination						
Personal Protective Equipment (*ANSI Table 10c.)							
Laser Eye Protection (UWLSP VII) (ANSI 4.4.4.1)	–	–	–	–	–	**X**	**X**
Skin Protection (ANSI 4.4.4.3)	–	–	–	–	–	●	●
Protective Clothing (ANSI 4.4.4.1 and 4.4.4.3.1)	–	–	–	–	–	●	●
Control Measures: Special Considerations (*Table 10d.)							
Laser Optical Fiber Transmission System Controls (ANSI 4.5.2)	MPE	MPE	MPE	MPE	MPE	**X**	**X**
Laser Robotic Installations (ANSI 4.5.3)	–	–	–	–	–	**X** NHZ	**X** NHZ
Summary of Area Warning Signs (Table 11a)							
Area Warning Device (audible / visible) (ANSI 4.4.2.8)	–	–	–	–	–	●	**X**
Laser Controlled Area DANGER Sign (ANSI 4.6.2.1)	–	–	–	–	–	–	**X**
Laser Controlled Area WARNING Sign (ANSI 4.6.2.2)	–	–	MPE	MPE	MPE	**X**	**X**
Laser Area CAUTION Sign (ANSI 4.6.2.3)	–	–	**X**	**X**	**X**	–	–

LEGEND		
	X Shall	MPE Shall if MPE is exceeded
	● Should	NHZ Nominal Hazard Zone analysis required
	– No Requirement	Φ May apply with use of optical aids
	▼ Shall if enclosed Class 3B or Class 4	UWLSP: UW Laser Safety Plan

[2] For explanations of standard requirements, copies of ANSI Z136.1-2014 are available from the Laser Safety Officer.

4. All energy sources associated with Class 3B or Class 4 lasers shall be designed to permit lockout/tagout procedures required by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA).

5. Lasers shall be disabled with the key removed when the laser is not in use for prolonged periods (e.g., laser storage).

C. Operation of Class 3B and Class 4 lasers.

1. The Laser Supervisor shall not permit the operation of Class 3B or Class 4 lasers without the approval of the LSO and unless there is adequate control of laser hazards to employees, students, and the general public.

2. For Class 3B and 4 laser systems, the Laser Supervisor shall ensure standard operating procedures (SOPs) are developed and followed if exposures could exceed maximum permissible exposures (MPE).

3. Class 3B and Class 4 lasers shall be operated at all times under the direct control of an authorized operator who shall maintain visual surveillance of conditions for safe use and terminate laser emission in the event of any condition of unsafe use.

4. If Class 3B or Class 4 laser systems cannot be operated under direct visual surveillance:

   a. The laser radiation in any accessible area shall be maintained below maximum exposure levels by control measures approved by the LSO (e.g., beam traps, barriers, and windows).

   b. Adequate laser safety training shall be provided to all who may enter the uncontrolled area.

5. The Laser Supervisor must train all Laser Operators under his/her supervision on all laser standard operating procedures. Standard operating procedures shall also be necessary for alignment, maintenance and/or service, and emergency response.

6. All Class 3B and 4 lasers shall be operated in laser controlled areas, the requirements of which are to be determined by the LSO. Refer to Table 3 for more information.

   a. The minimum requirements for Class 3B and 4 laser controlled areas are:

i) Posting of area warning signs containing the laser symbol, appropriate precautionary instructions, the type and the class of the laser, and the following appropriate signal word:
DANGER – only for multi-kilowatt Class 4 lasers
WARNING – for other Class 4 and Class 3B lasers

ii) A well-defined beam path.

iii) Administrative entryway controls to allow only authorized personnel or approved spectators to enter the laser control area.

b. All Class 4 and Class 3B laser controlled areas shall have:

i) Laser safety eyewear available and used in accordance with the safety procedure.

ii) Beam control (barriers and beam blocks) to reduce transmission of direct or reflected laser beams outside of controlled areas to below maximum permissible exposure (MPE) levels.

iii) Secured laser such that the exposed beam path is above or below eye level of a person in standing or sitting position.

iv) Only diffusely reflecting materials in or near the beam path, where feasible.

v) Storage or disabling of the laser when not in use to prevent unauthorized use.

vi) Engineered entryway controls (Class 4 only)

(i) Non-defeatable safety latches, entryway, or area interlocks to activate the laser in the event of unexpected entry are strongly preferred, or

(ii) Defeatable safety latches, entryway or area interlocks, if non-defeatable controls limit the intended use of the laser and if there is no laser radiation hazard at the point of entry; or

(iii) If safety latches or interlocks are not feasible: At the entryway a door, blocking barrier, screen, curtains, etc. shall be used and an activation warning system shall indicate when the laser is operating at Class 4 levels.

VII. Eyewear policy

A. In accordance with applicable regulations, standards and the UW Eye Protection Policy, the LSO will determine the requirements and proper ocular density (OD) for protective eyewear. In general, the eyewear requirements are:

B. Specifically designed laser protection eyewear is required within the nominal hazard zone (NHZ) for the operation of Class 4 lasers with exposed beams.

C. Laser safety eyewear is normally required within the nominal hazard zone (NHZ) for the operation of all Class 3B invisible lasers and for Class 3B visible lasers with powers greater than 15 mW.

D. Eyewear is not required by policy for Class 3B or below visible lasers with powers of 15 mW or less if other controls are adequate and if intentional viewing time is less than 0.25 seconds.

VIII. Medical surveillance

A. Baseline eye exams are not required. An eye exam is required immediately following a suspected laser exposure. Any suspected laser exposure must be reported to the Laser Safety Officer immediately.

IX. Administrative records

A. Audits

1. An audit of all Class 3B and 4 lasers and the Laser Safety Program shall be conducted annually by the LSO.

B. Records

The LSO shall maintain records which document the Laser Safety Program. These records shall include:

1. Inventory and hazard analysis for Class 3B and 4 lasers
2. Training records for operators of Class 3B and 4 lasers
3. Standard operating procedures for all Class 3B and Class 4 lasers
4. Documentation of medical surveillance, if performed
5. Laser Safety Audit reports

APPENDIX A

Non-beam ancillary hazards

Many non-beam hazards are present in laser laboratories. It is the responsibility of the Laser Supervisor to take precautions to prevent injury due to these hazards.

I. Electrical hazards

The majority of laser systems involve high potential, high current power supplies. Serious accidents and fatalities have resulted from laser system electrocutions. Where applicable, laser systems should comply with OSHA standards for Electrical Safety-Related Work Practices (29 CFR 1910 Subpart S) and control of Hazardous Energy (lockout/tagout; 29 CFR 1910.147).

A. Make sure that high voltage systems are off, locked out, shorted, and that high-energy capacitors are fully discharged prior to maintenance or repair. Beware that charges on capacitors may have been restored after initial discharge.

B. Frames, enclosures and other accessible non-current-carrying metallic parts of laser equipment should be grounded.

C. Class 3B and 4 lasers shall have a separate circuit and local cut-off switch (breaker) for the circuit.

D. Appropriate marking should be used, warning of electrical hazards and listing the primary electrical rating in volts, frequency and power or current.

II. Fire hazards

Class 4 lasers will easily ignite flammable materials (e.g., paper, cloth, vapors). Class 3 lasers can sometimes also ignite flammable vapors.

A. Use flame retardant materials wherever applicable.

B. Segregate flammable liquids.

C. A properly rated fire extinguisher shall be readily accessible.

III. Laser Generated Air Contaminants (LGAC)

Interaction of laser beams with target materials can result in the production of toxic chemicals. Characteristics of the contaminants depend upon the target material, cover gas, and beam irradiance.

A. To prevent inhalation and release of LGAC to the environment, exhaust ventilation with special filters may be needed.

IV. Chemical hazards

Lasers use a variety of lasing mediums. Some of these (dyes, solvents and gases) are toxic, carcinogenic or cryogenic materials.

A. Consult the Material Safety Data Sheet (MSDS) for hazardous properties and precautions for dyes and solvents.

B. Supervisors must ensure that all individuals who work with laser dyes and solvents receive appropriate training on hazardous material handling, storage, and disposal.

V. Noise

A. Noise levels 90 decibels (dB) or higher may require hearing protection.

VI. Hazardous radiation other than primary laser beam

A. X-rays

Some high voltage systems with potentials greater than 15-30 kV may generate X-rays at significant dose rates. High power (kJ) electron pumped excimer lasers, plasma systems and ion sources operated at high voltages can generate significant X-ray levels.

1. These devices shall be checked by EHS upon installation to ensure adequate shielding is included.

2. Free electron lasers are driven by powerful ionizing radiation devices regulated by the UW Radiation Safety Committee.

B. Plasma Radiation

Materials can be made incandescent when exposed to Class 4 lasers. These “blue light” spots can cause serious eye injuries. Laser protective eyewear may not protect against such exposures.

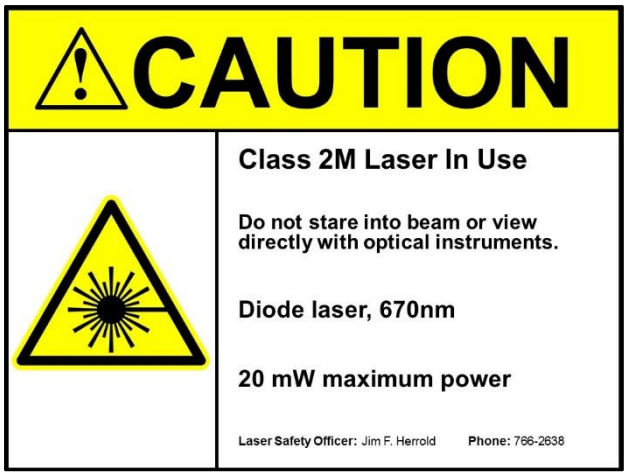
1. Whenever possible, view such spots through suitable filters such as TV cameras, etc.

C. Ultraviolet (UV) and Visible Radiation

May be generated from laser discharge tubes and pump lamps. Can cause skin and eye damage.

APPENDIX B

Sample Area Signs for Class 2M, Class 3B and Class 4 Lasers[3]



Sample Class 2, 2M or 3R CAUTION sign

Sample Class 3B WARNING sign

Sample Class 4 WARNING sign (<multi-kW)

Sample Class 4 DANGER sign (multi-kW)

[3] Templates for these signs may be found on the EHS Laser Safety web page: http://www.uwyo.edu/ehs/programareas/radiationsafety/lasersafety.html

APPENDIX C
Glossary of Laser Terms

Absorbance: The ability of a medium to absorb radiation depending on temperature and wavelength. Expressed as the negative common logarithm of the transmittance.

Accessible exposure limit (AEL): The maximum allowed power within a given laser classification.

Administrative controls: Control measures incorporating administrative means (e.g., training, safety approvals, LSO designation, and Standard Operating Procedures) to mitigate the potential hazards associated with laser use.

American National Standards Institute (ANSI): The technical body which releases the Z136.1 Standard for the Safe Use of Lasers. The secretariat for the Z136.X standard series is the Laser Institute of America (LIA).

Attenuation: The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Average power: The average power of a pulsed laser is the product of the energy per pulse (J/pulse) and the pulse repetition frequency (Hz or pulses/sec). The average power is expressed in Watts (J/sec).

Aversion response: Closure of the eyelid, or movement of the head to avoid an exposure to a noxious stimulant or bright light. In this standard, the aversion response to an exposure from a bright laser source is assumed to occur within 0.25 s, including the blink reflex time.

Barrier: Any device(s) employed to partially (e.g., laser attenuative translucent window materials) or fully (e.g., opaque curtains) diminish or restrict the transmission of incipient laser light.

Beam bender: Hardware assembly or optical device, such as a mirror, capable of changing laser beam direction; used to re-point the beam and in “folded,” compact delivery systems.

Beam expander: Optical device increasing beam diameter and reducing divergence. The result is a smaller focused spot for more distance between the lens and the target.

Beam splitting: Optically splitting a laser beam into two or more beams, allowing work on more than one side of a target at the same time, but at somewhat less power than with a multiple output beam system.

Collateral radiation: A potentially dangerous by product generated from high power supplies associated with some lasers. A power supply that is 15KeV or greater may produce x-rays that can be a health hazard.

Collecting optics: Lenses or optical instruments having magnification and thereby producing an increase in energy or power density (e.g., lenses, telescopes, microscopes, endoscopes, and eye-loupes). NOTE – Normal or prescription eyewear is not considered collecting optics. Require controls, such as interlocks, filters, and attenuators, to maintain the laser radiation transmitted through the collecting optics to levels at or below the applicable MPE.

Collimation: The process by which divergent rays (white, or natural light) are converted into parallel rays or coherent light.

Continuous wave (CW) - The output of a laser, which is operated in a continuous rather than pulsed mode. In this text, a laser operating with a continuous output for a period >0.25 s is regarded as a CW laser.

Convergence: The bending of light towards each other, as by a positive (convex) lens.

Controlled area (Laser controlled area): An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards.

CW: Continuous wavefront. The continuous emission mode of a laser, as opposed to pulsed operation.

Diffuse reflection: A change in the spatial distribution of the laser beam by virtue of its reflective interaction in many directions by a non-specular (non-mirror like) surface or other reflecting medium.

Electromagnetic wave: A disturbance which propagates forward from an electric discharge which oscillates or is accelerated. Includes, Radio Waves, X-Rays, Gamma Rays, Infrared, Ultraviolet, and Visible Light.

Embedded laser: An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

Enclosed laser: A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place. An embedded laser is an example of one type of enclosed laser.

Engineering Control Measures: The primary and preferred method to ensure safe laser operation. They are comprised of measures designed, engineered and incorporated into a laser or laser system which require minimal to no training for individuals who may be exposed to laser output.

Exposure: A measure of the total radiant energy incident on the surface per unit area; radiant exposure.

Fail-safe interlock: A built-in control where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

Frequency: The number of light waves passing a fixed-point per unit of time or the number of complete vibrations in that period of time.

Heat Sink: A substance or device used to dissipate or absorb unwanted heat, as from the manufacturing process (or with lasers from reflected rays.)

Infrared (IR) radiation: Invisible radiation with a wavelength between 780 nm and 1 mm. The near infrared (IR-A) is the 780 to 1400 nm band, the mid infrared (IR-B) is the 1400 to 3000 nm band, and the far infrared (IR-C) is the 3000 nm to 1 mm band.

Intrabeam viewing: The viewing condition whereby the eye is exposed to all or part of the laser beam.

Intensity: The magnitude of radiant energy (light) per unit, such as time or reflecting surface.

Invisible laser: Lasers that emit radiation outside of the visible radiation spectrum. This is commonly wavelengths below 400nm (ultra violet) or above 700 nm (infrared).

Irradiance (E): The power being delivered over the area of the laser beam. Also called power density, irradiance applies to CW lasers and is expressed in W/cm2.

Irradiation: Exposure to radiant energy such as heat, X-rays or light; the product of irradiance and time.

Joule: One watt per second; a measurement of frequency given for a laser output in pulsed operation.

Laser: An acronym of Light Amplification by Stimulated Emission of Radiation. A laser is a cavity that has mirrors at the ends and is filled with lasable material such as crystal, glass, liquid, gas, or dye. These materials must have atoms, ions, or molecules capable of being excited to a metastable state by light, electric discharge, or other stimulus. The transition from this metastable state back to the normal ground state is accompanied by the emission of photons which form a coherent beam.

Laser classification: An indication of the beam hazard level of a laser or laser system during normal operation. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4. In general, the potential beam hazard level increases in the same order.

Laser controlled area: (See Controlled area)

Laser Generated Air Contaminants (LGAC): Interaction of laser beams with target materials resulting in the production of toxic chemicals. Characteristics of the contaminants depend upon the target material, cover gas, and beam irradiance. See Appendix A.

Laser Safety Officer (LSO): One who possess the authority and responsibility to monitor and to enforce the control of laser hazards and to effect the knowledgeable evaluation and control of laser hazards in order to establish a laser or laser system's safe use.

Laser Safety Plan (UWSLP): A document defining the University of Wyoming Laser Safety Program. Copies are available from the Radiation Safety Office, or on the web site: http://www.uwyo.edu/ehs/programareas/radiationsafety/lasersafety.html.

LSO: (See Laser Safety Officer)

Luminance: Commonly called illumination; the luminous or visible flux per unit area are on a receiving surface at any given point.

Maintenance: Performance of those adjustments or procedures (specified in user information provided by the manufacturer with the laser or laser system), which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this section.

Maximum Permissible Exposure (MPE) - The maximum level of radiation which human tissue may be exposed to without harmful effect. MPE values may be found in the ANSI Z136.1 Standard.

MPE: See Maximum Permissible Exposure.

NHZ: (See Nominal Hazard Zone)

Nominal Hazard Zone (NHZ): The space within which the level of the direct, reflected or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

Non-beam Hazard: A class of hazards that result from factors other than direct human exposure to a laser beam.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include maintenance or service as defined in this section.

Optical aid or instrument: Viewing enhancement (e.g., binoculars, telescopes, magnifying glasses) resulting in a diverging or collimated beam, which could focus the laser on the sensitive portion of the eye.

Optical Density (OD): A logarithmic expression for the attenuation of the irradiation produced by an attenuating medium, such as an eye protection filter.

Power: The rate at which energy is emitted, transferred, or received. Unit: Watts (Joules/second).

Protective Housing: An enclosure that surrounds the laser or laser system that prevents access to laser radiation above the applicable MPE level. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated optics and a workstation and shall limit access to other associated radiant energy emissions and to electrical hazards associated with components and terminals.

Pulsed laser: A laser that delivers its energy in the form of a single pulse or a train of pulses. In this text, the duration of a pulse is less than 0.25 s.

Repetitive Pulsed Laser: A laser with multiple pulses of radiant energy occurring in sequence with a pulse repetition frequency greater than or equal to 1 Hz.

Service: Repair to laser or laser system beyond regular maintenance. This must be performed by a professional trained on repairs on your particular laser or laser system.

Shall: The word *shall* is to be understood as mandatory.

Should: The word *should* is to be understood as advisory.

Spectator: An individual who wishes to observe or watch a laser or laser system in operation, and who may lack the appropriate laser safety training.

Specular Reflection: A mirror-like reflection.

Transmittance: The ratio of total transmitted radiant power to the total incident radiant power.

Ultraviolet Radiation (light): Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of laser safety, 200-400 nm.

UWLSP: (See Laser Safety Plan)

Visible radiation (light): Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range of 400-700 nm. The colors (with approximate wavelengths) are: Violet (400 - 440 nm), Blue (440 - 495 nm), Green (495 - 545 nm), Yellow (545 - 575 nm), Orange (575 - 605 nm), and Red (605 - 780 nm).

Watt: The unit of power or radiant flux. 1Watt = 1 Joule/second.

Wavelength: The distance between two successive points on a periodic wave which are in phase.